Data-Driven Study on the Evolution of Forms and Types of Ancient Luoyang Coins

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Abstract. This study delves into the evolution of ancient Luoyang coinage in terms of its forms and types. Leveraging big data technologies, the Selenium library combined with Python scripting was employed to drive web searches and capture data related to ancient Luoyang coins. Subsequently, the PyQuery library was utilized to parse search results and extract pertinent data. All retrieved data, such as casting epochs, shapes, and materials, underwent preprocessing and were stored in a MongoDB database, ensuring efficient querying capabilities. The systematic analytical framework guaranteed data integrity and precision. In-depth data analysis unveiled the coinage techniques behind ancient coins and their developmental trends across various historical epochs. Through this research, the historical and cultural significance of ancient Luoyang coins is further illuminated. The comprehensive application of big data technologies not only offers a fresh perspective on ancient Luoyang coins but also furnishes invaluable insights for interdisciplinary studies.

Keywords: Ancient Luoyang coinage; Big data technologies; Data parsing; Cultural significance

1   Introduction

Luoyang, an esteemed ancient capital of China, possesses a wealth of ancient coins reflecting its economic, social, and cultural journey from the Xia-Shang era to the late Qing dynasty. These coins offer deep insights into the historical context and monetary dynamics of ancient Luoyang. Through archaeological efforts, numerous coin artifacts have been uncovered in Luoyang, offering tangible evidence of its multifaceted heritage. The artistic designs and crafting techniques of these coins captivate scholars in the arts, while researchers in economics, political science, and folklore delve into their cultural significance, enriching modern perceptions of ancient Luoyang's vast legacy [1].

Ma [2] investigated the evolution of ancient coinage from economic and ideological angles, enhancing our grasp on its value in economic exchanges. Deng [3] analyzed ancient texts to uncover the societal and cultural implications of ancient currency, providing a nuanced view of its role in historical contexts.

This study aims to delve deeply into and decipher the historical evolution of ancient Luoyang coins, as well as their characteristics and values in different periods. Furthermore, it seeks to offer modern scholars a more efficient and comprehensive approach to studying ancient currencies.

Traditional methods studying Luoyang's ancient coins grapple with challenges like massive data volumes and fragmented sources. As the history of these coins stretches across millennia, relevant information is scattered throughout literature, museums, and collections. The advent of big data technology presents a novel solution, allowing for efficient processing and revelation of underlying trends in the data of these ancient coins.

Big data technology boasts formidable data processing and storage capabilities [4, 5]. Where traditional research methods often require considerable time and effort to organize and cleanse data, big data technology can process vast datasets swiftly and efficiently. By leveraging big data, it becomes feasible to integrate ancient Luoyang coin data from diverse sources into a unified database. Consequently, researchers can access and analyze data more conveniently, enhancing research efficiency.

To achieve the stated objective, this study initially employs big data technologies, particularly data mining techniques, to collect and consolidate data on ancient Luoyang coins from various sources. Subsequently, specific algorithms and tools are utilized to deeply analyze the data, extracting crucial insights on the coins' historical evolution, morphological features, and casting techniques. This process encompasses not just data collection and processing, but also data visualization and interpretation to better comprehend and present the research findings.

Big data technology significantly enhances the study of Luoyang's ancient coins by facilitating advanced data mining and analysis [6]. Beyond examining limited samples, it reveals hidden patterns from extensive datasets using advanced algorithms. Moreover, this technology supports data visualization, presenting intricate coin details more intuitively. Such visualization not only aids in academic comprehension but also communicates findings effectively to the broader audience, amplifying the research's impact.

Using data mining techniques, comprehensive data on Luoyang's ancient coins including their shape, inscriptions, era, and material can be meticulously analyzed. These methods allow for a deeper understanding of the coins' historical evolution. This chapter aims to harness big data technology to examine the development of Luoyang's ancient coins, offering novel insights into Luoyang's culture.

2   Data mining and analysis methods

In the study of Luoyang's ancient coins, data collection is a crucial step. With the aid of big data technology, research can employ various methods and tools to gather data related to Luoyang's ancient coins, establishing a comprehensive and enriched dataset. This section will introduce the methods and tools for acquiring data on Luoyang's ancient coins using big data technology and discuss the steps and techniques for data preprocessing and cleansing.

(1) Methods and Tools to Acquire Data on Luoyang's Ancient Coins through Big Data Technology

Researchers utilize the Python programming language in conjunction with a series of tools and techniques to gather data pertinent to Luoyang's ancient coins. The following presents a data collection process based on the Python language. Figure 1 illustrates the data mining workflow for this study.
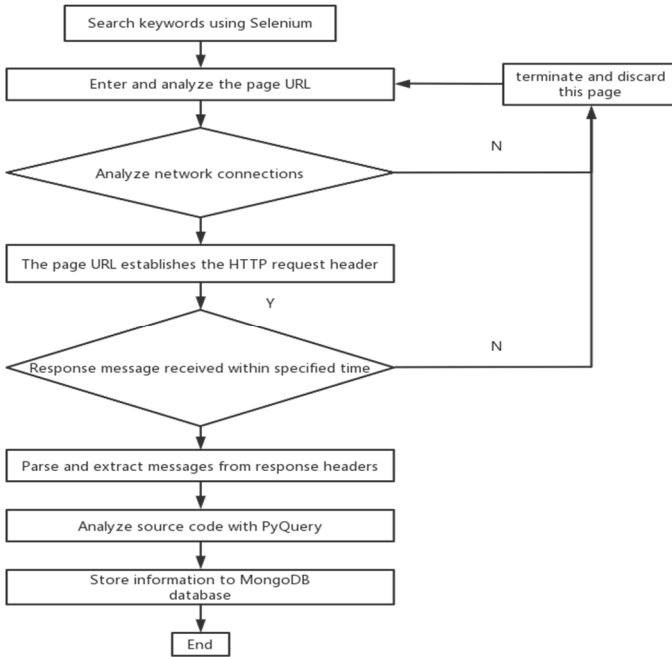

Fig. 1. Flow chart of data mining

Using Selenium [7] in Python, we automate browser actions to search and scrape data on Luoyang's ancient coins. This library enables automatic browsing, including simulated pagination, ensuring thorough data collection from search results.

Once the information listings from search result pages are secured, the PyQuery library can be utilized to parse and extract data from these pages. PyQuery is a powerful parsing library in Python, akin to jQuery. It facilitates the easy extraction of desired data from HTML sources. Utilizing PyQuery, information related to ancient Luoyang coins can be extracted from each search result. The search results include: 1. Detailed descriptions outlining specific types of ancient Luoyang coins. 2. Historical documents or manuscripts that discuss or reference these coins. 3. Museum or collection entries that delve into the coin's specifications and its significance. 4. Academic articles or research studies focusing on the ancient Luoyang coins, shedding light on their production techniques, materials used, and cultural relevance. 5. Image databases providing visual representations of the coin, with close-up views highlighting intricate

designs or markings. 6. Auction or sale listings offering further insights or appraisals regarding a specific coin variant.

(2) Steps and Techniques for Data Preprocessing and Cleaning

After acquiring data related to Luoyang's ancient coins, it's essential to preprocess and clean the data to ensure its accuracy and consistency. Below are the preprocessing steps and techniques used in this research.

Firstly, deduplication of data is conducted. During the data collection process, duplicate data may arise. Such redundancies are meaningless for analysis and mining. The Python Set data structure can be employed to eliminate duplicates, ensuring the uniqueness of each data item.

Data normalization is vital to ensure consistency across varied formats from different sources. This includes standardizing casting years to date formats and categorizing designs using set criteria. Rectifying missing or wrong values is crucial, with methods like imputation or deletion used to maintain data integrity. It's also key to detect and manage outliers, which can arise from errors or anomalies. Outliers can be identified using statistical methods or visualization. For effective analysis, data should undergo normalization to scale values or standardization to achieve a common distribution, neutralizing scale differences.

This research uses MongoDB [8] to store and manage data on Luoyang's ancient coins. MongoDB's flexible structure and powerful querying capabilities make it ideal for handling semi-structured data. Table 1 presents entries for the coin database, where each document captures attributes like casting year and design, ensuring efficient data access.

Table 1. Database storage information

Basic attributes and historical information of coins	Cultural and Religious Information on Coins	Legendary and literary information related to coins	Historical transaction and collection information of coins
Coin name, material, shape	Coin front and back decorations	emperor or official praised by coins	Coin history transaction records
Coin quality, diameter, age	Coin Minting Techniques and Historical Uses	Legends or myths related to coins	Coin Collection Information
Where and how many coins were minted	Coin Minting Office and Circulation Scope	Poems or texts related to coins	Sources of coins and cultural relics
coin preservation	religious symbols of coins		coin market value
The historical and cultural background of coins	The cultural connotation of coins		

MongoDB's robust querying and indexing allow swift analysis of Luoyang ancient coin data. With its indexing, researchers can efficiently query specific attributes, such as casting years or design types. The Aggregation Pipeline feature aids in complex data

aggregation, enabling tasks like counting and averaging, providing insights into Luoyang coin history.

MongoDB's distribution and scalability features handle vast datasets with high concurrency, thanks to horizontal scaling and sharding. With Python-based data collection tools like Selenium and PyQuery, we extract web data on Luoyang's coins, ensuring accuracy through preprocessing and cleaning. MongoDB's flexible, scalable database is essential for storing and managing this data. Combining big data techniques with MongoDB offers a comprehensive research perspective on Luoyang's ancient coins.

3   The historical development of the shape and type of ancient Luoyang coins driven by data

Using big data techniques, we've amassed extensive data on Luoyang's ancient coins from sources like museum collections, market transactions, and historical literature. Tools like Selenium and PyQuery automate keyword searches, retrieving vast lists of results, and parsing source codes for comprehensive coin data. This section delves into the historical development research of these coins based on this data.
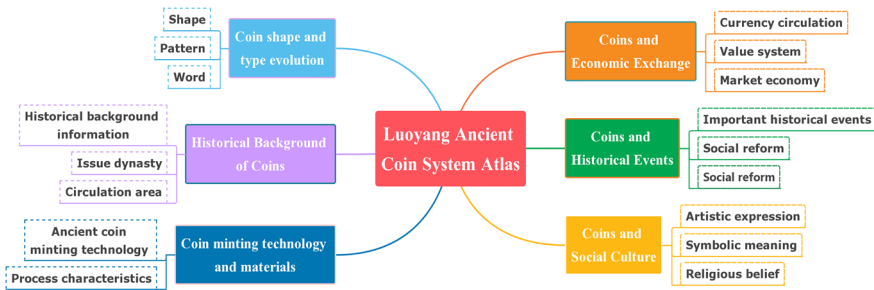

Fig. 2. Big Data System Map of Luoyang Ancient Coins

As illustrated in Figure 2, we have the big data schematic map of Luoyang's ancient coins. The data and information acquired through big data techniques offer crucial resources for an in-depth study of the historical evolution of Luoyang's ancient coins. By analyzing this data, we can observe the changes and evolution of the coinage forms and types throughout different dynasties. Researchers can identify characteristics and significant phases of ancient coins from various eras, as well as their roles and impacts in economic, social, and cultural contexts.

Luoyang's ancient coins, integral to its cultural heritage, span from the Xia and Shang eras to the late Qing dynasty. This section traces their evolution, reflecting the region's political, economic, and cultural shifts. Over time, the coins' forms and appearances transformed, showcasing unique features of each period.

The period from the Xia-Shang era to the early Qin dynasty marked the origin and initial development phase of Luoyang's ancient coins. In this era, people began to use

shells, animal teeth, and bronze objects as mediums of exchange. During the Western Zhou era, the Luoyang region saw the emergence of its earliest currencies, such as shell coins, copper shells, and copper fish coins. As depicted in Figure 3, these ancient coins had simple designs, primarily modeled after shells or bronze objects, and were used for commodity exchanges.
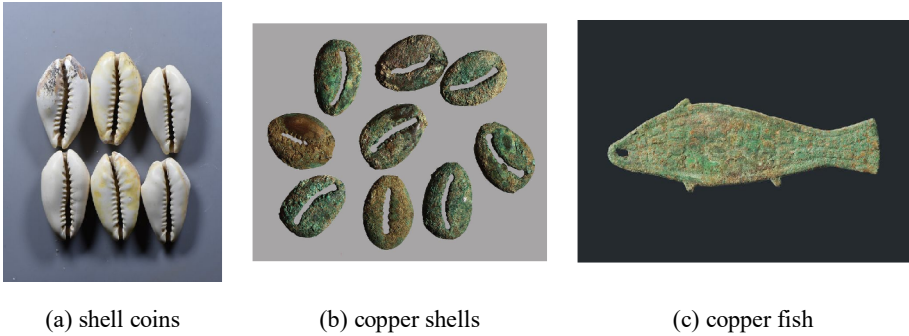

| (a) shell coins | (b) copper shells | (c) copper fish |

Fig. 3. Early currency

As shown in Figure 4, the period from the Qin and Han dynasties to the medieval era marked a phase of evolution and diversification in the designs and types of Luoyang's ancient coins. During the Qin and Han periods, a plethora of copper coins emerged in the Luoyang region, such as knife coins, spade coins, and half tael coins. These coins had relatively standardized forms and are regarded as significant milestones in the evolution of currency.
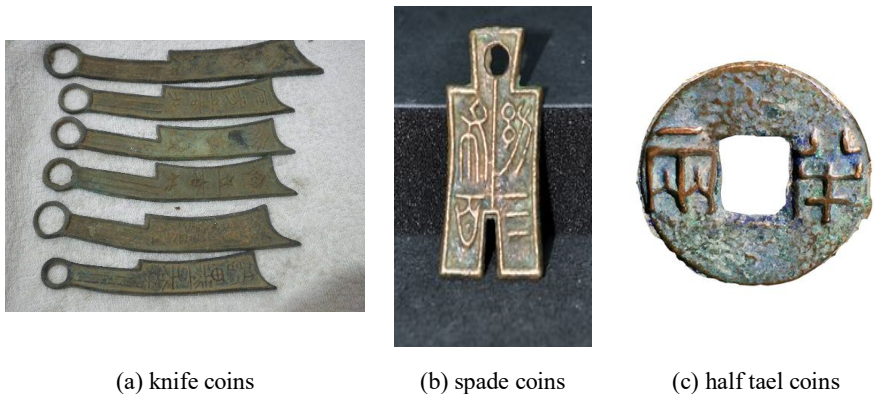

| (a) knife coins | (b) spade coins | (c) half tael coins |

Fig. 4. Luoyang currency from the Qin and Han Dynasties to the Middle Ages

As time progressed, the ancient coins of Luoyang evolved into more intricate and varied designs and types. During the Sui and Tang dynasties, Luoyang became the center of Chinese politics and culture, exerting a profound influence on the development of currency. Particularly in the Tang dynasty, there was a proliferation of iron and

copper coins in the Luoyang region. The square-holed and round-holed coins were the most iconic of this era. Figure 5 displays examples of Tang dynasty coins.

(a) The square-holed coins   (b) The round-holed coins

Fig. 5. Currency of the Tang Dynasty

In the Tang dynasty, Luoyang's ancient coins were central to economic activities. The Tang era, with its expansive territories and booming economy, recognized the significance of both square-holed and round-holed coins; the former for domestic use and the latter for overseas trade. Their circulation was crucial for trade and commerce, propelling the Tang economy.

Moreover, these coins were more than just currency; they were artworks and cultural emblems. Luoyang, being the Tang dynasty's heart, witnessed great artistic and cultural strides. The coins' inscriptions and designs, intricate and diverse, mirrored the era's aesthetics, encapsulating political messages, societal norms, scholarly sentiments, and even religious ideologies.

The Tang dynasty, a cornerstone in Chinese history, greatly influenced subsequent periods. Luoyang's coins from this era offer a rich tapestry of historical, economic, and cultural insights. By delving into their designs, we can understand the era's economic dynamics, cultural aesthetics, and philosophical leanings, providing a comprehensive view of Tang society.

From the Song dynasty to the Qing dynasty, ancient Luoyang coinage experienced significant evolution. As shown in Figure 6. In the Song era, copper coins dominated the Northern Song, while the Southern Song leaned towards lead coins. The introduction of paper currency, such as 'Jiazi' in the Northern Song and 'Huizi' in the Southern Song, signaled its forthcoming prominence. Subsequent dynasties, from the Liao to the Yuan, brought unique copper coin designs, each reflecting its era's cultural and political milieu. The Jin and Yuan dynasties, with their paper currency, laid foundations for future monetary systems.

The Ming and Qing periods saw copper coin designs diversify further, including those from distinct political entities like the Southern Ming and Taiping Heavenly Kingdom. The Qing dynasty introduced a myriad of coins, indicative of political and cultural transitions. The proliferation of paper money during these eras marked a leap in
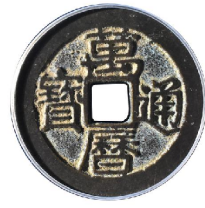
currency modernization. Alongside the common copper and lead coins, there were iron, gold, and silver coins—each holding specific significance in various periods and regions.

(a) Song coin   (b) Yuan coin   (c) Ming coin

(d) Qing coin   (e) Jiazi

(f) Huizi   (g) Gold coin   (h) Silver coin

Fig. 6. Coins of the Song, Yuan, Ming and Qing Dynasties

Ancient Luoyang coins played a pivotal role in the historical evolution from the Xia-Shang period to the end of the Qing dynasty. From simple shells and bronze currency to the diverse array of copper coins, the forms and types of Luoyang's ancient coins showcase a rich tapestry of change and development. These transformations not only mirror the shifts in monetary systems and economic growth but also stand as testaments to societal, political, and cultural metamorphoses.

4   Data analysis results and findings

Ancient Luoyang coins played a pivotal role in the historical evolution from the Xia and Shang dynasties to the end of the Qing dynasty. From simple seashells and bronze currency to intricate and diverse copper coins, the form and types of Luoyang's ancient coins exhibit a rich tapestry of changes and developments. These shifts not only represent the transformation of the monetary system and economic progression but also bear witness to the societal, political, and cultural metamorphoses over time. As shown in Figure 7, through the analysis of the timeline diagram, this study proposes the following main findings:
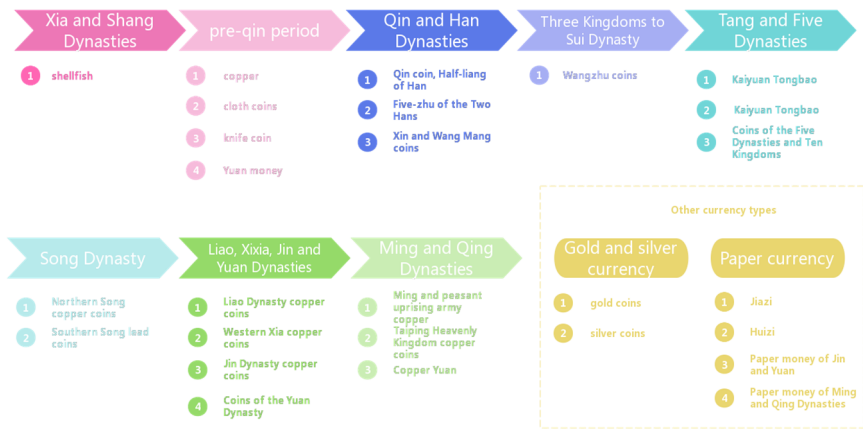
Fig. 7. Timeline diagram

Chinese currency originated from primitive shell money. As the Iron Age progressed, metallic currencies like copper, cloth, and knife coins evolved. This laid the foundation for a unified monetary system, boosting societal progress.

The Qin and Han dynasties initiated the standardization of currency, with coins like the Han's Wuzhu symbolizing both trade and political power. Their legacy has deeply impacted later generations.

From the Three Kingdoms to the Sui, diverse currencies arose, mirroring various regimes' economic control and identity ambitions. The Tang dynasty, with the Kaiyuan Tongbao, further institutionalized the currency system, enhancing Silk Road trade.

The Song dynasty marked the debut of paper currency, positioning China as its pioneer. This innovation simplified large transactions but brought issuance challenges. The Ming and Qing eras faced currency upheavals, especially with increased global contact and the influx of precious metals. Notably, rebel factions during these times introduced distinct currencies, underlining the interplay between currency, political legitimacy, and identity.

This currency evolution, from simple to intricate and singular to diverse, reflects China's socio-economic dynamics, political shifts, and technological advances across eras.

5   Discussion

Liu Jingcheng [9] categorized currency evolution into three phases tied to societal systems, offering insights into its historical development. Shen Duanmin [10] explored the nomenclature culture of ancient currency, highlighting its cultural significance over time. Guo Fangfang [11] examined the changes in China's ancient monetary system, providing suggestions for modern reforms.

Current research on ancient Luoyang coins faces challenges. Traditional methods, relying on literature reviews and excavations, struggle to process extensive coin data, and preservation efforts are often inadequate. Given the coins' long history and significance, a comprehensive analysis is essential.

To overcome these limitations, this study harnessed big data technologies, offering a new lens for analyzing ancient Luoyang coins. Big data allows for efficient processing and analysis of vast datasets, capturing details like coin types, inscriptions, and designs. Where traditional methods falter with large datasets, big data reveals hidden patterns, enriching our understanding of the coins' evolution and variety.

Data mining, which uncovers hidden patterns from large datasets [12, 13], was instrumental in analyzing ancient Luoyang coins to reveal their cultural and historical contexts. Unlike previous studies limited by data volume, big data technology enables a comprehensive view of coin evolution. This approach uncovers previously unnoticed insights, deepening our understanding of ancient societies' economic, political, and cultural facets. The incorporation of big data not only refreshes ancient coin studies but also presents new research opportunities.

6   Conclusion and Outlook

Using big data, this study comprehensively analyzed the evolution of Luoyang's ancient coins, constructing a detailed database from various sources. Data mining revealed overlooked patterns, offering insights into ancient Luoyang's monetary culture and society. As big data and AI technologies advance, future research will likely use more sophisticated tools for detailed coin analysis, while technological innovations like virtual reality could popularize coin culture. In essence, data technology opens new avenues for understanding and sharing ancient Luoyang's heritage, promising exciting developments ahead.

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